110-500 kV substation, Electromagnetic compatibility, Pioneering works, Stray pick-ups calculation, Grounding calculations, Electromagnetic fields calculation

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PROJECTING OF ELECTROMAGNETIC COMPATIBILITY AT 110-500 kV SUBSTATIONS

Article is devoted to method of electromagnetic compatibility (EMC) projecting at 110-500 kV substations, that was developed at directorate "Energosetproject" of Urals Power Engineering Company. Article depicts main results of 4 years EMC projecting experience including pioneering works and special engineering calculation principles.

PROJEKTOWANIE KOMPATYBILNOŚCI ELEKTROMAGNETYCZNEJ NA PODSTACJACH 110-500 kV

Artykuł jest poświęcony metodyce projektowania kompatybilności elektromagnetycznej na podstacjach 110-500 kV, która była opracowana dla zarządu "Energosetprojekt" "Inżynierny centrum energetyki Uralu" SA. W artykule są opisane główne wyniki 4 lat projektowania kompatybilności elektromagnetycznej włącznie z metodyką badania gruntu i wykonania specjalnych inżynierskich kalkulacji.

1. INTRODUCTION

Nowadays at modern 110-500 kV substations is used a big amount of microprocessor devices, used in substations automatics, relay protection, telemechanics, communications. All these devices have low levels of normal working stability in hard electromagnetic situation that exists on high voltage substations. That is why since 2006 all 110-500 kV substation projects at directorate "Energosetproject" of Urals Power Engineering Company include special part, devoted to projection of electromagnetic compatibility. Since that time until april 2010 we made more than 20 EMC projects. This article depicts our main results of 4 years EMC projecting experience.

Development of 110-500 kV substation EMC project consists of the following steps:

1) pioneering works;

2) special engineering calculations including stray pick-ups calculation, grounding calculations and calculation of electromagnetic fields;

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3) choice of microprocessor devices EMC parameters and projecting of special protection means.

All these steps should be depicted in EMC project.

2. PIONEERING WORKS

Traditionally all projecting works start with pioneering. According to art. 47.1 of Building code of Russian Federation [1], projecting without pioneering works is even forbidden. But, according to art. 47.5 of the same law [1], volume of pioneering works is regulated in project statement. And that was the problem at the first period of our EMC projecting experience – project customers didn't want to invest additional funds for special pioneering works, that are needed to make special engineering calculations. The reason of such a problem was that the base pioneering works for building projects include the research of type of ground, where substation will be build, and at standard [2] there are regulated specific ground resistances, that could be used also in EMC project.

Pioneering works for substation building project includes ground research (test boring) only for 10 m, and for correct development of EMC project project designer needs data about specific ground resistance minimum for 100 m. Test boring for such depth is very expensive and certainly couldn't be made because of economic reasons. But there exists one more method for measuring specific ground resistance for deep depths – method of deep electric probing, and use of this method in EMC projects shows good results.

Method of deep electrical probing (fig. 1) is based on indirect method of ground resistance measuring (method of amperemeter and voltmeter). With use of these method we can measure ground resistances on any depth, but practically we measure for 100 m depth and calculate two-level ground model, that includes two specific ground resistances $\rho 1$ and $\rho 2$. Second ground level with specific ground resistance $\rho 2$ starts from depth h.

Pioneering works for EMC projects we make with use of special instrument KDZ-1 (fig. 2), calculations of two-level ground model (fig. 1) – with use of program ORU-M (reg. №2002611768).

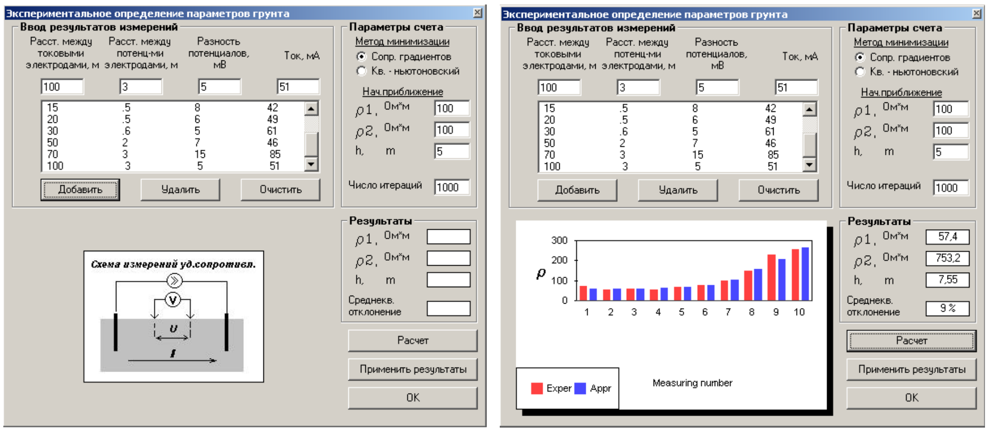

Fig. 1. Method of deep electrical probing

Fig 2. Instrument for deep electrical probing KDZ-1

3. STRAY PICK-UPS CALCULATION

Stray pick-ups calculation at 110-500 kV substation is a main part of EMC project. To make these calculations we use program Interferences (reg. №2004610419).

Stray pick-ups calculation consists of the following steps.

1. Primary acquisition including results of pioneering works, electrical scheme, plan and sections of substation, characteristics of high voltage wires and control cables, single-phase short circuit currents for 110-500 kV bus systems and three-phase short circuit currents for 6-35 kV bus systems.

2. Bus systems, high voltage equipment and control cables modelling (fig. 3).

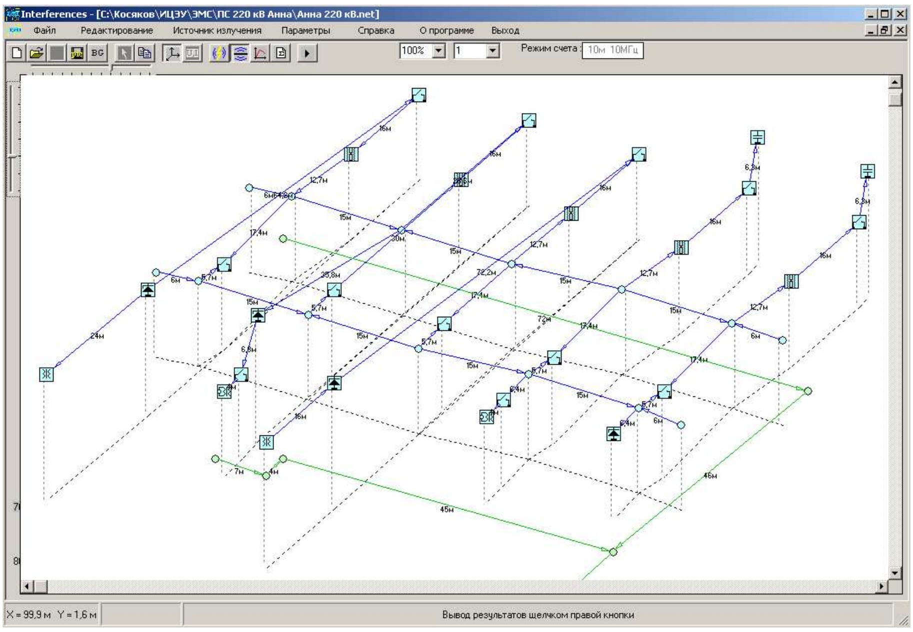

Fig 3. Bus systems, high voltage equipment and control cables modelling (3D view)

At fig. 3 with blue colour are shown 220 kV bus system and equipment – current breakers, disconnectors, power and measuring transformers, overvoltage limiters and lines, modelled as capacities. With green colour are shown control cables, where stray pick-ups will be calculated.

To decrease time of calculation processes usually we make separate models for high voltage part and for lightning protecting system of substation.

3. Calculation of stray pick-ups, that appear in control cables during short circuits at high voltage equipment and bus systems.

During developing the program of calculations it is very important to choose the places on the scheme, where short circuit at high voltage equipment and bus systems will result maximum levels of stray pick-ups in control cables. Developing of this part of project needs high quality and experience of project designer. Mainly there should be chosen places of short circuits, situated at bus systems, parallel to main control cables lines.

Usually calculation program of this step of stray pick-ups calculation consists of 10-30 calculations for one 110-500 kV substation. As a result of calculations we receive diagrams of transients, that will apper in control cables during short circuits at high voltage equipment and bus systems (fig. 4).

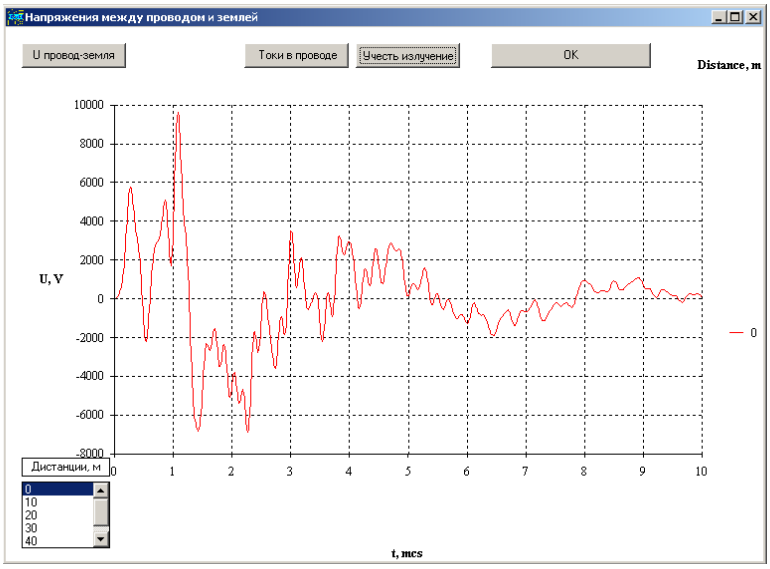

Fig 4. Result of pick-ups calculation

4. Calculation of stray pick-ups, that appear in control cables during commutations of current breakers and disconnectors. Developing of this part of project also needs high quality and experience of project designer because of the same problems of correct choice of parts of electric scheme, that will be commutated by current breakers and disconnectors.

Usually calculation program of this step of stray pick-ups calculation consists of 6-30 calculations for one 110-500 kV substation. As a result of calculations we receive diagrams of transients, that will apper in control cables during commutations of current breakers and disconnectors (fig. 4).

5. Calculation of stray pick-ups, that appear in control cables during lightning strikes at lightning protection system of substation.

Usually lightning protection system of substation consists of several pin lightning conductors and we calculate stray pick-ups, that appear in control cables during lightning strikes at each lightning conductor. Calculation program of this step of stray pick-ups calculation consists of 4-30 calculations for one 110-500 kV substation. As a result of calculations we receive diagrams of transients, that will apper in control cables during lightning strikes at lightning protection system of substation (fig. 4).

6. The final step of this part of project is comparing the results of stray pick-ups calculation to permissible levels of stray pick-ups for microprocessor devices [3, 4]: first level – 0,5 kV, second level – 1 kV, third level – 2 kV, fourth level – 4 kV. If stray pick-ups have higher levels (as it is shown on fig. 4), we use additional projects decisions devoted to screening and limiting overvoltages:

– connection of control cables casings to substations grounding;
– use of metal cable trays;
– use of overvoltage limiters.

Use of additional projects decisions devoted to decreasing stray pick-ups levels is also modelled in program Interferences. Practically with use of combination of these project decisions we can decrease stray pick-ups levels in 7…180 times, and it's enough for every substation project.

4. GROUNDING CALCULATIONS

Grounding calculations for EMC projects we make with program ORU-M – the same program that is used for calculations of two-level ground model (fig. 1).

Grounding calculations consist of the following steps.

1. Primary acquisition including results of pioneering works, plan and characteristics of substations grounding (type of metal, section and depth of grounding elements laying), single-phase short circuit currents for 110-500 kV bus systems.

2. Grounding elements and control cables modelling (fig. 5). Usually this model contains elements of lightning protection system, that are conducted to substations grounding.

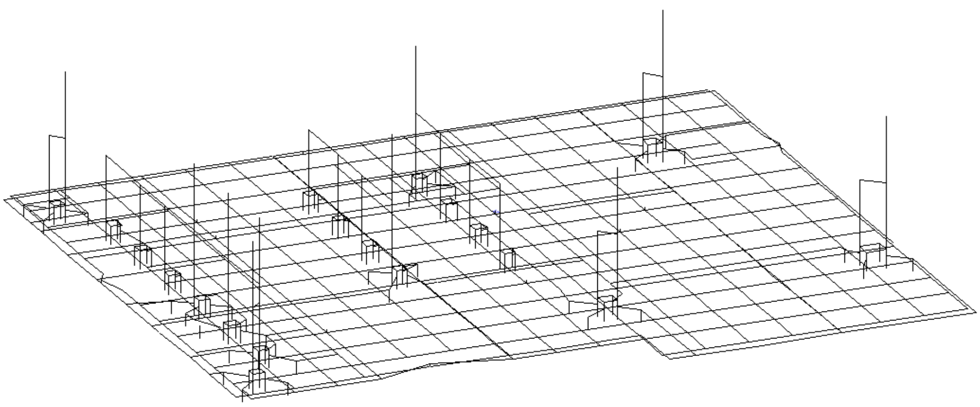

Fig 5. Grounding and lightning protection system modelling (3D view)

3. Calculation of grounding resistance and voltages, that appear on every element of grounding during short circuits and lightning strikes.

According to standard [5], grounding resistance of 110-500 kV substation should be lower than 0,5 Ω and voltage, that appears on every element of grounding, should be lower than 10 kV. To achieve these results we change configuration of substations grounding, usually by adding to grounding additional grounding elements.

As an exception (when specific ground resistance is high) we use original two-level grounding [6]. The first upper level of this grounding is connected to substations power equipment, the second lower level – to lightning conductors (fig. 6). So, stray pick-ups, that appear during lightning strikes, don't affect on substations power equipment and control cables, which casings are connected to grounding. To reduce substations grounding resistance two levels of grounding are connected between each other at the borders of grounding. This decision practically don't affect stray pick-ups level.

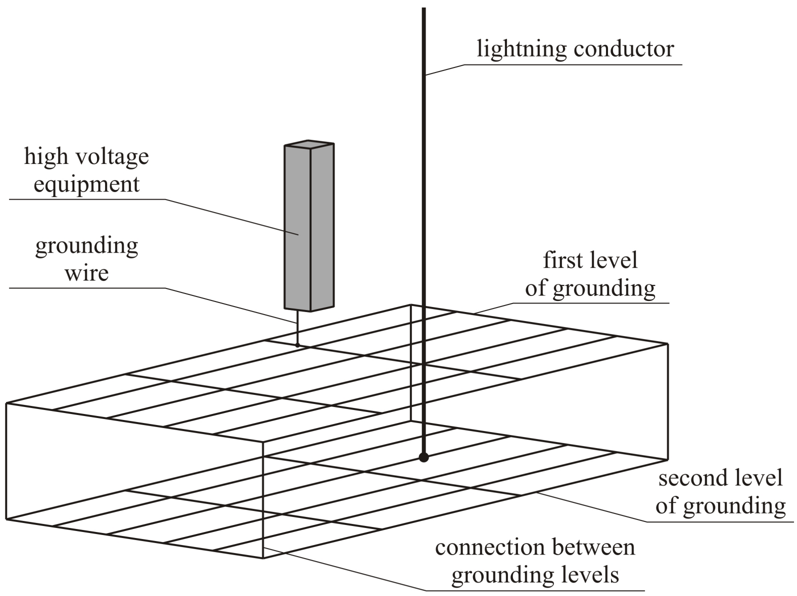

Fig 6. Two-level substations grounding (3D view)

4. If, according to the results of stray pick-ups calculation, in EMC project was used additional project decision – connection of control cables casings to substations grounding, we should also calculate currents, that are flowing in control cables casings during short circuits. This calculation should be made to ensure that control cables casings will bear short circuits currents flowing. As a result of calculations we receive diagrams of voltages and currents, that will apper in grounding elements and control cables casings during short circuits (fig. 7).

At fig. 7 with black colour are shown horizontal grounding elements, with red colour – vertical grounding elements and grounding wires and with blue colour – control cables casings. After calculation currents in control cables casings we make a calculation of their thermal stability with use of standard method [5].

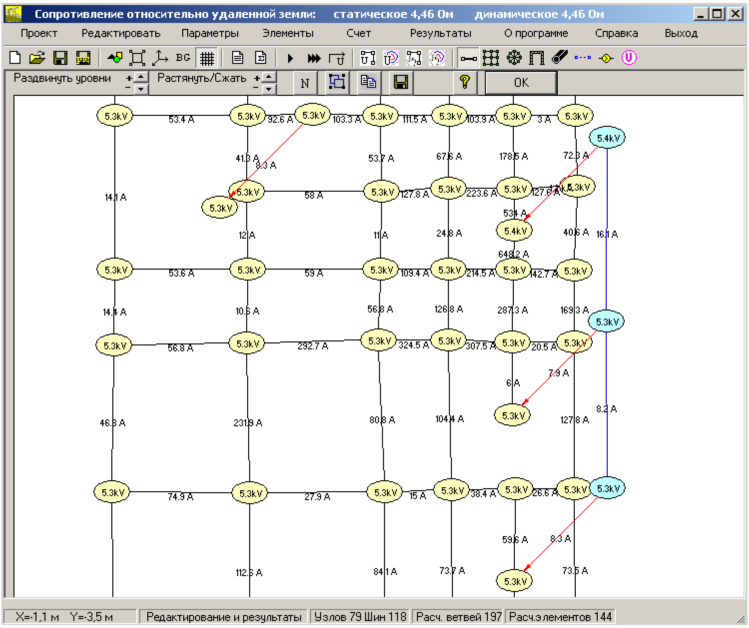

Fig 7. Results of grounding calculations

5. CALCULATION OF ELECTROMAGNETIC FIELDS

According to standards [7, 8, 9], EMC project should contain calculation of electromagnetic fields intensity at the places of microprocessor devices location. At 110-500 kV substations all microprocessor devices are located in one place – at operations point of control. So, electromagnetic fields calculation for EMC project includes only three calculations in one point: electric field calculation, power frequency and impulse magnetic fields calculation. Calculations are made with use of programs EMP VL (reg. №2006613744) and Reactor MP (reg. №2006613743).

Calculation of electromagnetic fields consists of the following steps.

1. Primary acquisition including electrical scheme, plan and sections of substation, characteristics of high voltage wires and single-phase reactors, maximum working currents, single-phase short circuit currents for 110-500 kV bus systems and three-phase short circuit currents for 6-35 kV bus systems.

At this step we always have a problem with acquisition of single-phase reactors characteristics, because producers of reactors don't want to give their characteristics to project designers because of, as they say, it is a commercial classified information. This problem should be solved legislatively.

2. Bus systems and single-phase reactors modelling in programs EMP VL and Reactor MP and calculation of electromagnetic fields. Calculations of electric field and power frequency magnetic field are made in maximum working regime, calculation of impulse magnetic field – in short circuit regime.

3. Comparing the results of electromagnetic fields calculation with normative parameters of microprocessor devices immunity to electromagnetic fields (tab. 1).

Tab. 1. Normative parameters of microprocessor devices immunity to electromagnetic fields

Microprocessor device immunity level	**Electric field intensity, kV/m**	**Magnetic field intensity, A/m**	
		Power frequency magnetic field	**Impulse magnetic field**
1	0,1	1	–
2	1	3	–
3	10	10	100
4	100	30	300
5	–	100	1000

6. CONCLUSIONS

The results of this work are the following conclusions.

1. Article presents original method of EMC projecting at 110-500 kV substations, that was developed at directorate "Energosetproject" of Urals Power Engineering Company and has 4 years of practical experience. EMC projecting at substations demands high engineering qualification, special equipment and programs.

2. Main problems of EMC projecting are:

– correct choice of places of short circuits and commutation schemes during stray pick-ups calculation;

– primary acquisition of single-phase reactors characteristics.

3. Method of EMC projecting at 110-500 kV substations is still in development and could be changed in future.

7. REFERENCES

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